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IMPACT OF HERBICIDE ON MOSSY SORREL (*RUMEX CONFERTUS*), AND PHYTOPHAGOUS *HYPERA RUMICIS, APION MINIATUM* AND *PEGOMYA NIGRITARSIS*

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ABSTRACT

A field experiment was conducted to determine a direct effect of five herbicides selected on *Rumex confertus* Willd., and an indirect effect on phytophagous insects. Mossy sorrel is the host of *Hypera rumicis* L. (*Coleoptera, Curculionidae*), *Apion miniatum* Germ. (*Coleoptera, Curculionidae*), and *Pegomya nigritarsis* Ztt. *(Diptera, Anthomyiidae*). The herbicide treatment affected the plant growth, yet new leaf rosettes were produced again by the end of the summer. However, the herbicide treatment reduced the leaf area and the number of seeds damaged by larvae. The insect development, seasonal adult abundance, and feeding by larvae decreased significantly on the herbicide treated plants.

Key words: herbicides, sub-lethal effects, growth, *Rumex confertus* Willd., biological agent, *Hypera rumicis* L., *Apion miniatum* Germ., *Pegomya nigritarsis* Ztt.

INTRODUCTION

R. confertus is a perennial weed that produces from 100 to 40,000 seeds and usually flowers in July/August. It is common in Poland and in the world [15] and it is considered to be one of the most noxious weeds globally.

The chemical control of this weed is difficult. After applying chemicals, the green parts of the plant dry out, yet shortly afterwards, new leaves emerge [16, 17]. In addition, chemical treatments can induce the breakdown of plants resistance [2].

The herbicides can be directly toxic to herbivorous insects, which may reduce sorrel populations significantly [27], and may alter the food suitability for insects [10]. They can, for example, reduce the weed biomass for herbivorous insects [22]. Predatory species may be limited by lower preying. Besides, insects may consume the contaminated plant material, resulting in toxic effects [26]. Simply, the plants become toxic to insects when treated with herbicides [10]. Finally, pesticides may act as repellents for insects [9].

An alternative to the pesticide treatments are biological methods which involve herbivorous insects [11]. A traditional biological control is usually understood as an environmentally safe practice of insect pest or weed management [1]. The development and application of biological weed control offer great opportunities for farmers. Potential agent organisms show features that make them particularly strong and useful for biological control [18]. An increasing interest is stimulated largely due to major economic, social, and environmental forces facilitating our choices of crop production practices [4]. *H. rumicis*, *A. miniatum*, and *P. nigritarsis* are of special interest, as representing numerous species infesting *Rumex* spp. [25]. Suitable biological control agents should have a high reproductive potential, a short life cycle, and no alternative hosts [20].

The aim of this study was to investigate an indirect influence of the herbicide on the development and survival of herbivorous insects feeding on *R. confertus* plants.

METHODS AND EXPERIMENTAL AREA

The experiments were carried out in 2003 and 2004. The field trials were located in the natural habitat of *R. confertus* in Bydgoszcz vicinity on the marshy meadow near Vistula river, Northern Poland ($53^0 13'$N, $17^0 51'$E). The laboratory study was conducted at Department of Entomology, University of Technology and Agriculture in Bydgoszcz.

Five herbicides were used in the experiment: Aminopielik Super 464 SL, Glean 75 WG, Harmony 75 WG, Refine 75 WG, and Superselectyl 435 SL. They are herbicides generally used for broadleaf weed control.

H. rumicis, *A. miniatum*, *P. nigritarsis* were selected for that experiment as model species for numerous reasons. *H. rumicis* larvae show a low mobility, occur on the inflorescence stems, while *A. miniatum* larvae are stem- and leaf-petioles-boring, all of which makes the species potential biological control agents for their host plant.

The sprayer was a 12 l, hand-held Kwazar (Kwazar Corporation S.C.) with a lance 0.6 to 1.2m long, and a double filtration system.

The five plants selected (in 5 replications) were sprayed with a solution of the test chemical preparation in the middle of May for *P. nigritarsis*, and in the middle of June for *H. rumicis*, *A. miniatum* insects. Five control plants were sprayed with water only.

The field experiments:

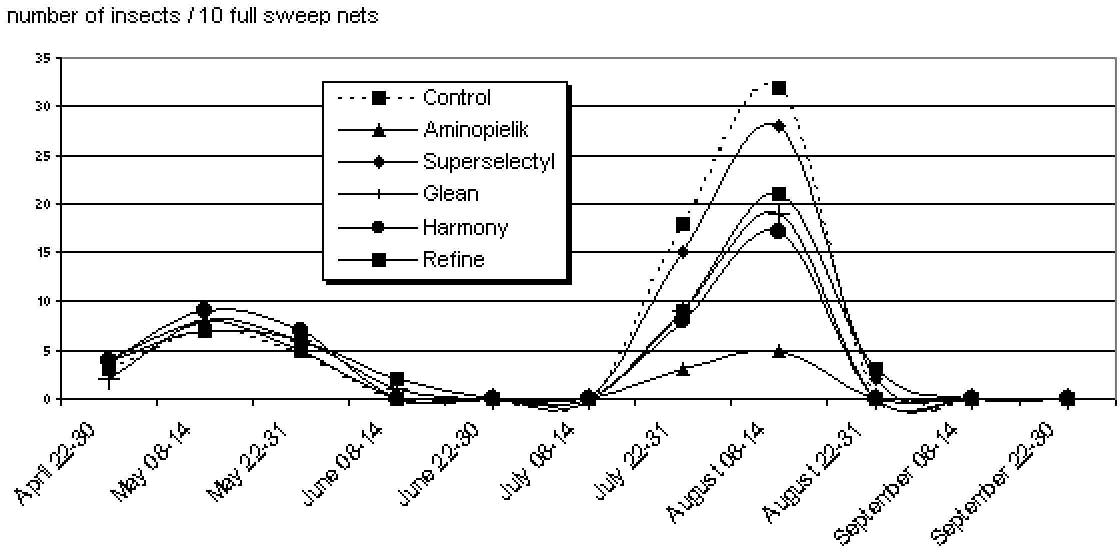
1. Studies evaluating the composition and development of plants, and the changes in insect population were carried out throughout the experimental period from spring to autumn. Observations of the biology of insects, such as their occurrence and other species damaging the plants were performed throughout the plant-growing season (May – September). Insect developmental stages were determined, which allowed estimating the number of generations throughout the vegetation period. Sampling was performed once every fortnight; the larvae caught were counted and then released; each time 10 full sweep nets (two per rosette), which resulted in 5 plants tested.
2. The number of seeds damaged by *H. rumicis* larvae, larvae abundance on the plants, number of inflorescence stems, leaf petioles damaged by *A. miniatum* larvae, and the number of leaves mined by *P. nigritarsis* larvae were recorded a week after the herbicide application.

Mean amounts were separated after analysis of variance using Tukey's test for significant differences at $\alpha = 0.05$.

RESULTS

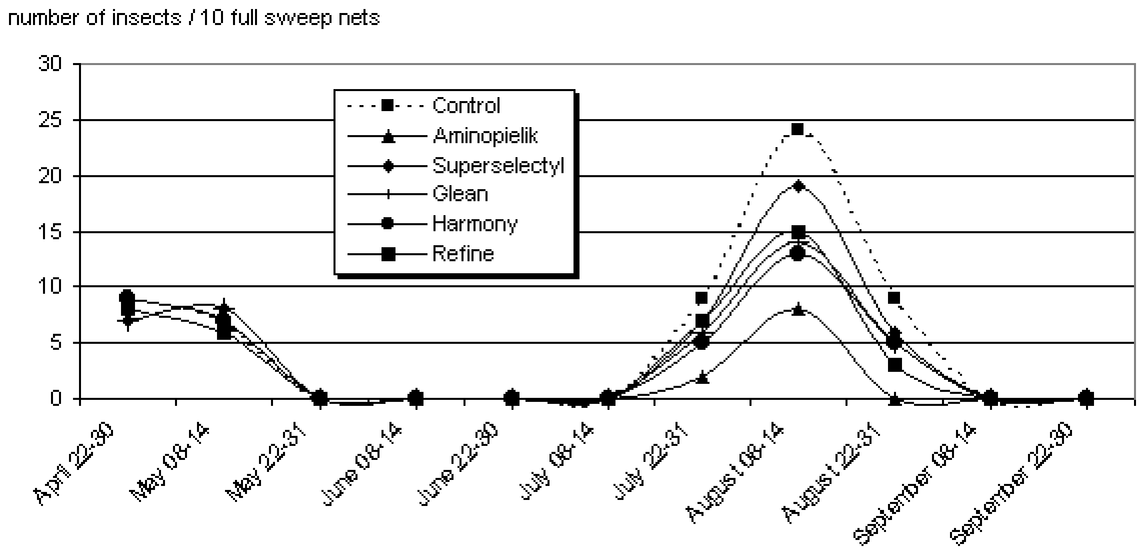
In the control plants grown up from April to late July, the inflorescences appeared at the beginning of July, according to the standard seasonal phenology of the plant. As for herbicide treatments, Aminopielik seemed to be the strongest. Moderate herbicide effectiveness was noted for the other herbicides, as even the plants damaged by those chemicals were still green. The lowest pesticide activity was recorded for Superselectyl. Another natural characteristic of mossy sorrel plants is growing again late in July. As for the control and for the plants treated, no large differences in biomass were recorded.

Fig. 1. Influence of the herbicide on the average number of *H. rumicis* adults on *R. confertus* plants in 2003 and 2004



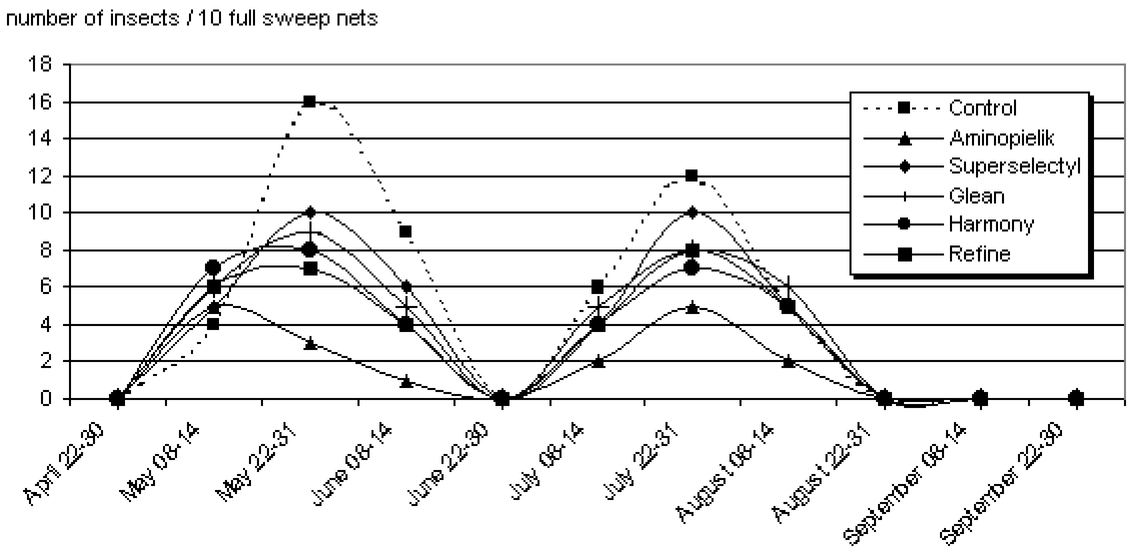
The number of *H. rumicis* adults is presented in Fig. 1. The control insects were not stressed by any herbicide; they were developing, and reached the number of over 30 individuals at the first stage. Aminopielik apparently changed the leaf taste, and/or odour, which restricted feeding of *H. rumicis* adults, causing the highest avoidance of the plant. Superselectyl did not seem to be so harmful to insects, yet also slightly decreased the abundance of insects. Glean, Harmony, and Refine also affected the seasonal abundance of insects. Approximately 10 fewer insects were caught, as compared with the control plants.

Fig. 2. Influence of the herbicide on the average number of *A. miniatum* adults on *R. confertus* plants in 2003 and 2004



The number of *A. miniatum* adults is presented in Fig. 2. The highest number of insects caught was recorded for control plants, which reached almost 25 individuals in the middle of August. Similarly Aminopielik restricted feeding of *A. miniatum* adults, causing the highest avoidance of the plant, but Superselectyl did not seem so harmful to insects. Seasonal abundance of the insects observed was also affected by Glean, Harmony, and Refine.

Fig. 3. Influence of the herbicide on the average number of *P. nigritarsis* adults on *R. confertus* plants in 2003 and 2004



The number of *P. nigritarsis* adults is presented in Fig. 3. Two generations per year were recorded during the growing season. The first generation developed in May/June, and the second one in July/August. Aminopielik seemed to be the strongest repellent to *P. nigritarsis* insects. Seasonal abundance of the insects observed was also affected by the other herbicides.

Table 1. Number of seeds of one mossy sorrel plant damaged by *H. rumicis* larvae

Objects	2003	2004	Average for years
Control	10526.8	10704.0	10615.4
Aminopielik Super 464 SL	316.2	309.6	312.9
Harmony 75 WG	4567.8	4160.6	4364.2
Glean 75 WG	4646.4	4682.8	4664.6
Refine 75 WG	4142.2	4249.6	4195.9
Superselectyl 435 SL	9176.6	8990.8	9083.7
HSD	348.8	304.4	150.1

H. rumicis larvae injured significantly *R. confertus* seeds (Table 1). In natural habitat they damaged over 10000 seeds. The healthy plant usually produces over 30000 seeds, which means that one third of all the seeds was damaged. The same trend was recorded in 2003, and 2004, as well as for avarage for years. This suggests that beetles were at least repelled by the odour of herbicides. In case of Aminopielik, insects damaged even 97% fewer seeds, as compared with the control insects.

Table 2. Number of *H. rumicis* larvae

Objects	2003	2004	Average for years
Control	62.0	58.4	60.2
Aminopielik Super 464 SL	7.6	8.6	8.1
Harmony 75 WG	33.2	27.4	30.3
Glean 75 WG	32.0	31.0	31.5
Refine 75 WG	35.0	28.8	31.9
Superselectyl 435 SL	58.2	52.2	55.2
HSD	4.9	3.0	1.5

The survival rate of the larvae was significantly reduced when the larvae infested the stems treated (Table 2). The herbicide treatment could have changed the nutritional status of the plant, thus causing an increased mortality rate. The survival rate of *H. rumicis* larvae was significantly affected by herbicide treatment of the host plant, especially by Aminopielik. The control plants were infested with approximately 60 individuals by the end of the second decade of June. Only for Superselectyl plants in 2003 the differences were not significant. In that case a significant mortality rate of larvae for the recommended dose of herbicides was observed.

Table 3. Inflorescence stems infested with *A. miniatum* larvae

Objects	2003	2004	Average for years
Control	22.2	22.2	22.2
Aminopielik Super 464 SL	12.6	14.0	13.3
Harmony 75 WG	19.4	20.0	19.7
Glean 75 WG	17.8	19.2	18.5
Refine 75 WG	17.6	18.4	18.0
Superselectyl 435 SL	20.0	21.6	20.8
HSD	2.6	2.4	1.2

The number of larvae boring the stems was affected (Table 3). The herbicides reduced the number of *A. miniatum* larvae occuring in the inflotrescence stems significantly, which must have had an indirect influence on the seed production.

Table 4. Leaf petioles infested with *A. miniatum* larvae

Objects	2003	2004	Average for years
Control	24.6	24.8	24.7
Aminopielik Super 464 SL	12.6	9.2	10.9
Harmony 75 WG	17.6	17.2	17.4
Glean 75 WG	19.4	18.4	18.9
Refine 75 WG	19.0	18.2	18.6
Superselectyl 435 SL	23.2	23.4	23.3
HSD	2.5	2.0	1.0

The survival rate of the larvae was reduced (Table 4). The survival of *A. miniatum* larvae in leaf petioles was significantly affected by the herbicide treatment of the host plant. Approximately 25% of all the control plants were infested with larvae. Similar results were recorded for the treatment with Superselectyl. The plants treated with Aminopielik repelled larvae that would have bored into the petioles.

Table 5. Leaves damaged by *P. nigritarsis* larvae

Objects	2003	2004	Average for years
Control	20.2	19.4	19.8
Aminopielik Super 464 SL	6.2	7.0	6.6
Harmony 75 WG	16.6	14.2	15.4
Glean 75 WG	17.0	16.4	16.7
Refine 75 WG	18.0	16.8	17.4
Superselectyl 435 SL	16.8	17.4	17.1
HSD	1.7	1.8	0.9

Significant results were recorded for all investigated herbicides (Table 5). Usually in natural conditions one fifth of all the plants is mined by *P. nigritarsis*. Large mines on leaves, often 20 cm long and 15 cm wide, were found. The larval feeding reduced the assimilation area and, occasionally, the plants, which were heavily damaged – dried out. The larvae were found in groups or single in small mines. Once the larvae completed the development stage, they dropped to the ground to pupate and to overwinter. For full development the larvae needed the amount of food which equaled three fourths of the leaf area. The plants treated with herbicide restricted the development of fly larvae. In case of Aminopielik, insects damaged even almost 70% fewer leaves, as compared to insects in the control.

DISCUSSION

Damaging generative organs responsible for the reproduction of the plant was an important destructive factor in weed development. This way of feeding is typical for *H. rumicis*. The feeding reduced the number of seeds. Adults, but first of all larvae, damaged the weeds. The whole mossy sorrel plant produces up to 30,000 seeds. In control plants more than 30% of them were directly damaged by *H. rumicis*. DeGregorio et al. [5] stated that the feeding of this insect species caused a colour loss of the green tissue of the plant.

P. nigritarsis reduced the growth of *R. conferus*. The larvae mining leaves caused serious damage and the mines contained one or a few larvae. The size of damage accounted for 75% of the blade area. Zimmermann and Topp [31] and Whittaker [29, 30] as well as Godfray [8] indicated negative effects on the plant water balance resulting from leafminer damage. According to Whittaker [30], stomas in small mines show a tendency to remain closed, while in the old ones – open. Godfray [8] is positive that there is a potential in researching other *Pegomya* ssp. flies.

Both imagines of *A. miniatum* and larvae were damaging the mossy sorrel plants. Adults were making holes in the leaf blades, while larvae were boring the stems and leaf petioles. Freese [6, 7], Scott and Shivas [19] noticed that larvae of *A. miniatum* might play an essential role in the reduction of *R. confertus* plants.

Herbicide-treated plants were a significantly less attractive food in comparison to the control, which suggests that beetles, and flies, as well as their larvae, were repelled by the herbicides or by the odour of chemicals. Mortality was recorded for all the recommended doses of herbicides. The survival rate of the larvae was significantly reduced. It seams possible that herbicide treatment may change the physiological status of the plant [28]. Speight and Whittaker [24] studied the controlling potential of *G. viridula* on *R. obtusifolius* and found that this beetle was unable to improve the control of the weed in combination with the herbicide Asulam under natural conditions. Sotherton and Moreby [23] observed that insects were absent from host plants in fields sprayed with herbicide the previous year, indicating that the dispersal to host plants or the ability to locate hosts were limited. Bueno and Freitas [3] reported that lufenuron induced high mortality in neonate larvae from the eggs treated and larvae could not molt. The results showed that lufenurom was toxic to *Chrysoperla externa* eggs and larvae. Manzano et al. [13] described substantially larger populations of whitefly nymphs, which occurred in the unsprayed field than in the sprayed field, as well as parasitoids, were more frequent in unsprayed than in the sprayed fields. Sotherton [21] found a reduced survival of the first instar larvae of *G. polygoni* after 2,4-D application to eggs or host plant leaves. Speight and Whittaker [24] reported on a reduced fecundity of female beetles.

Predators are potential control agents in field production [12], however they are subjected to direct toxic effects from herbicides and other pesticides. The selective use of pesticides that are harmless against natural enemies is necessary to achieve a program of integrated pest management [14].

CONCLUSIONS

1. Mossy sorrel (*Rumex confertus* Willd.), a weed of the polygonum family (*Polygonaceae*), was damaged by *Hypera rumicis* L., *Apion miniatum* Germ., *Pegomya nigritarsis* Ztt. The feeding was noted throughout the growing season, i.e. from the development of the leaf rosette to the drying-up of the plants.
2. In the field, the seasonal insects abundance was restricted by the herbicide treatment, especially with Aminopielik Super 464 SL. Insects avoided feeding on herbicide treated plants.
3. The herbicides investigated significantly affected the insects development, reducing their survival, especially those treated with Aminopielik Super 464 SL.
4. The seed production was not restricted by insects on the herbicide treated plants, especially those treated with Aminopielik Super 464 SL.

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